HUMAN ERROR MODELING

IMPRINT/ACT-R

Micro Analysis & Design

Carnegie Mellon University

Army Research Laboratory – Human Research & Engineering Directorate

Today's Discussion

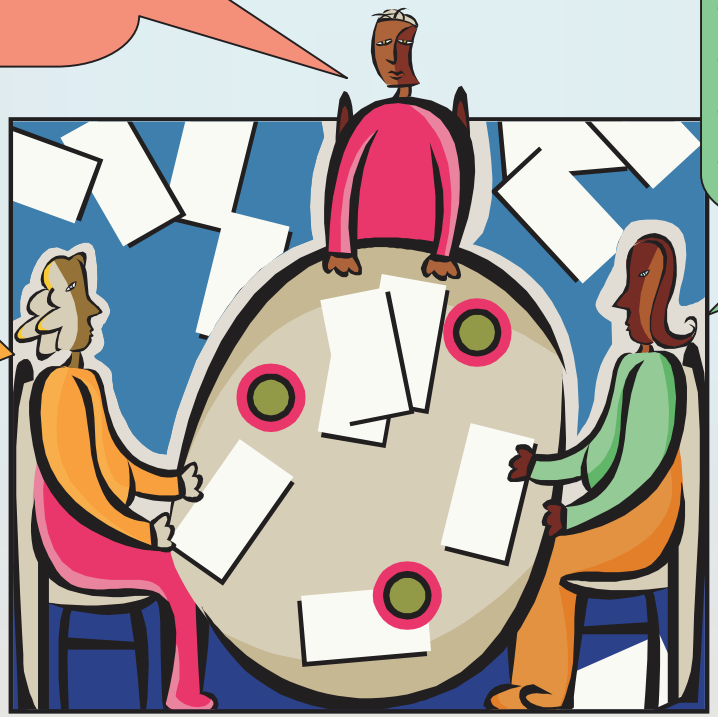
- The IMPRINT/ACT-R project team
- IMPRINT overview
- ACT-R overview
- The IMPRINT/ACT-R approach to human error modeling
- Central questions for modeling human errors
- General discussion of our approach

IMPRINT / ACT-R Team

What do we bring to the table?

Carnegie Mellon University
- Developers of ACT-R
- Cognitive modeling
- Human Computer Interaction

Micro Analysis & Design
- Developers of IMPRINT
- IMPRINT users
- Software integration
- Human Systems Integration

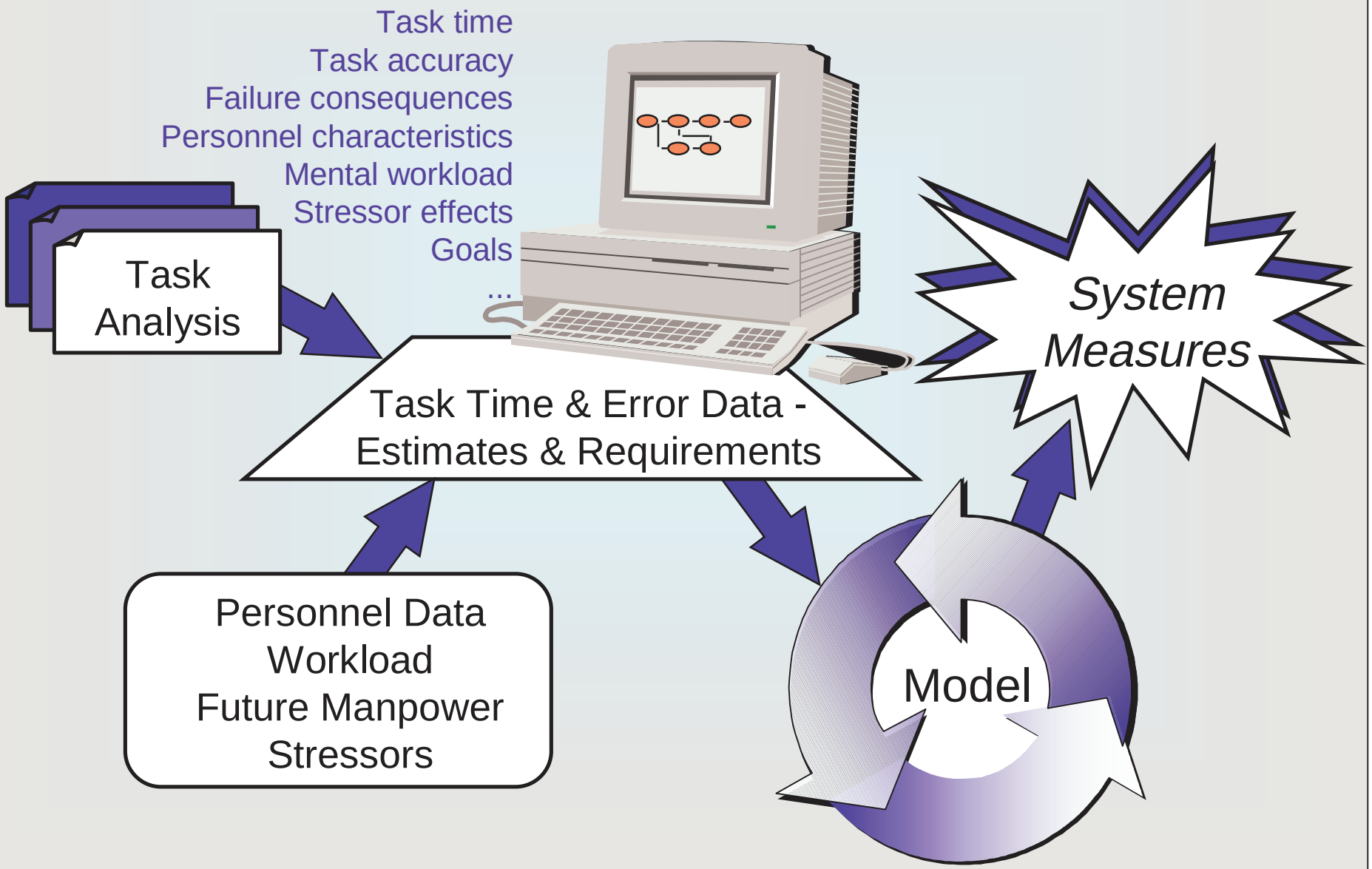


Army Research Lab
- IMPRINT designers
- IMPRINT users
- ACT-R users
- Research interest in error modeling
- And in human behavioral representation in Army models

Improved Performance Research Integration Tool (IMPRINT)

- Discrete-event network simulation development tool
- Owned by ARL and developed by MA&D
- Designed specifically for modeling human performance

IMPRINT Architecture



Mental Workload

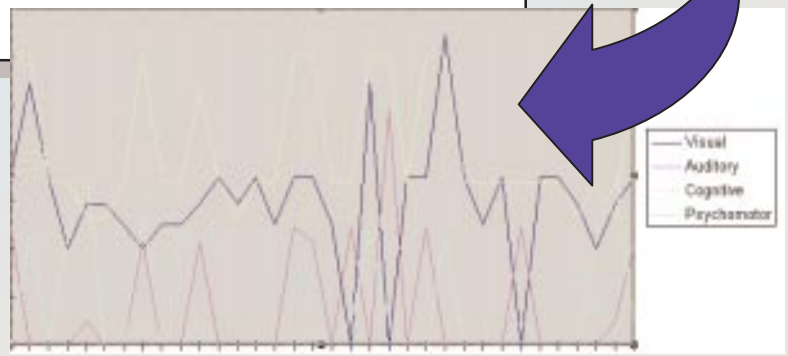
Flight Tasks → **Which Brain Resources Involved?** → **Degree of Resource Use?**

1. monitor alarms
2. decide response action
3. respond
.
.
n. task n

Visual
Cognitive
Auditory
Psychomotor

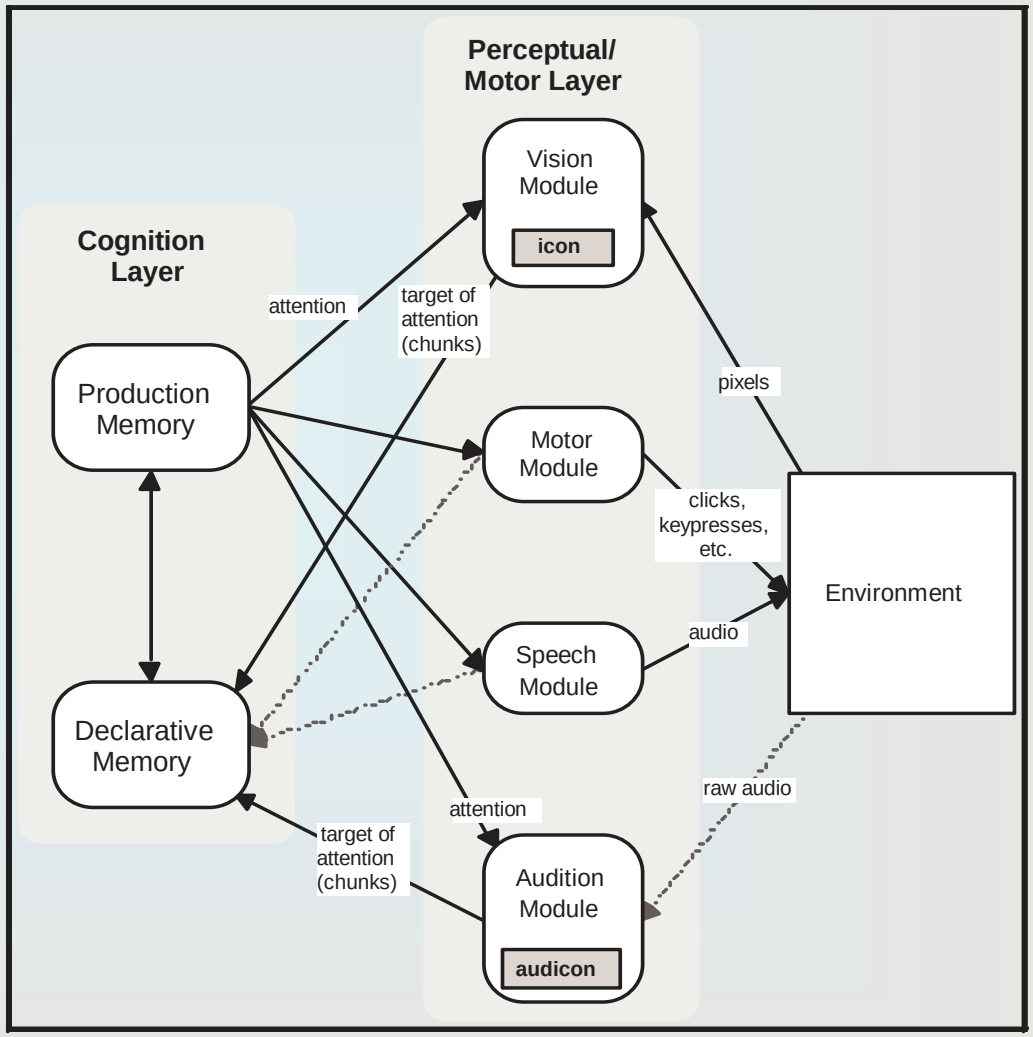
Visual
Auditory
Psychomotor
Cognitive

0.0	- No Cognitive Activity
1.0	- Automatic (simple association)
1.2	- Alternative Selection
3.7	- Sign/Signal Recognition
4.6	- Evaluation/Judgment (consider single aspect)
5.3	- Encoding/Decoding, Recall
6.8	- Evaluation/Judgment (consider several aspects)
7.0	- Estimation, Calculation, Conversion

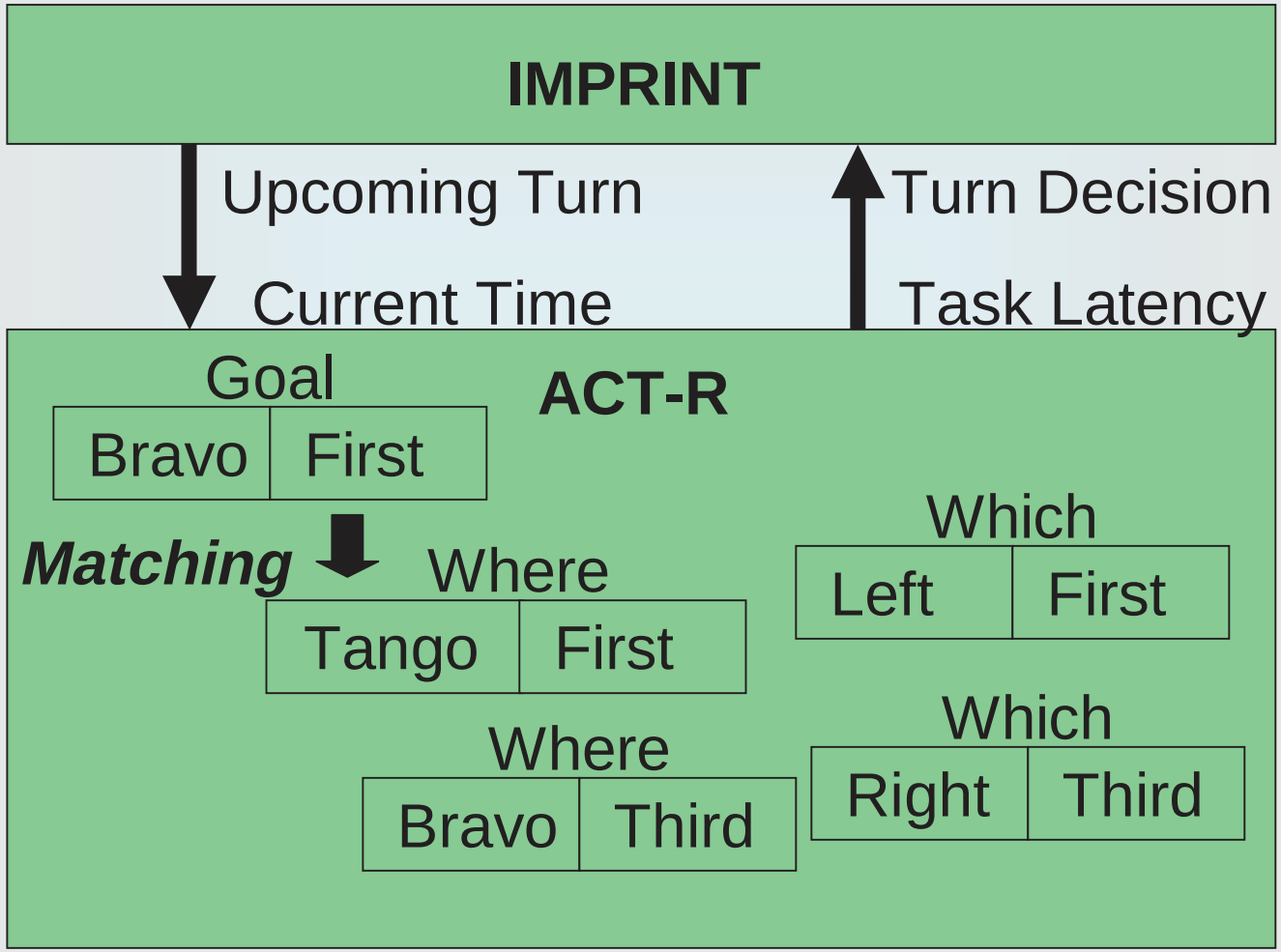


ACT-R

- Procedural memory
tltattroductotrulet
- eclarate memory
actattructured ctut
- ymbolt leel
etuetal ecutotot
abmt etotcobt
or tuctured eabr
- tymbolt leel
mately arallel atert
mattatleart
atallytadatet
rotutad bcatt
- Percetualtotor layer
ttted layer etteet
cobtad etotmet



Model

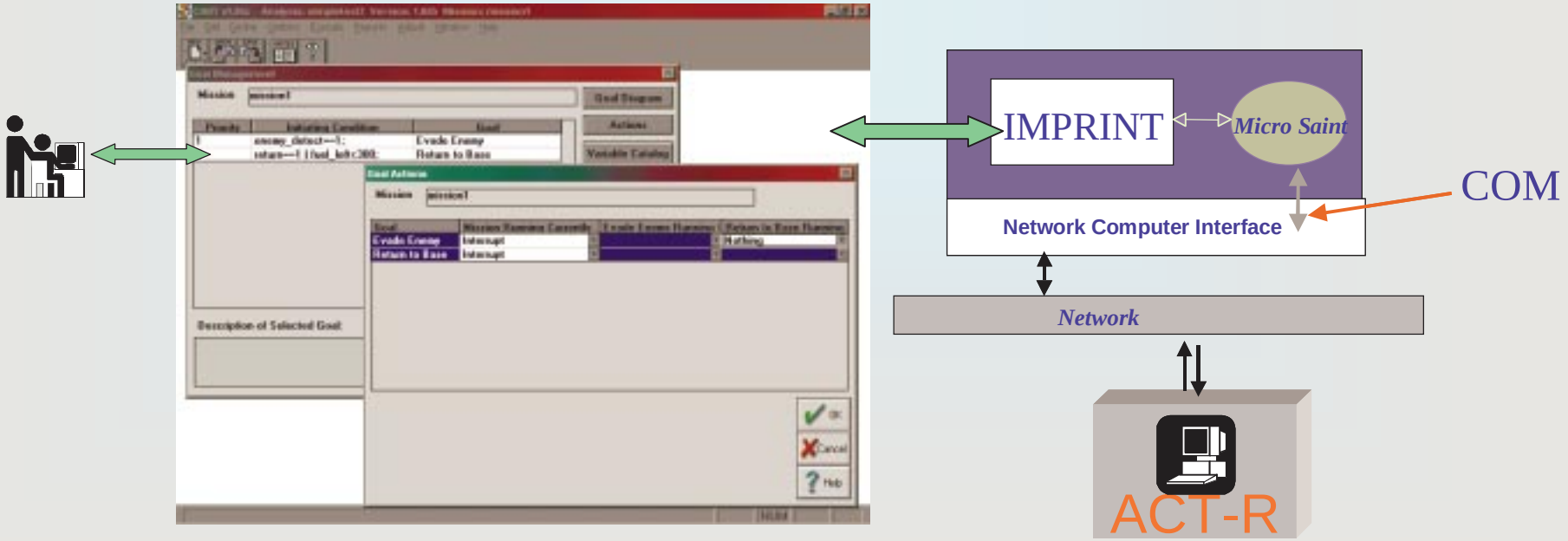

IMPRINT
Upcoming Turn
Current Time
Turn Decision
Task Latency
ACT-R
Goal
Bravo
First
Matching
Where
Tango
First
Which
Left
First
Where
Bravo
Third
Which
Right
Third

Memory Errors

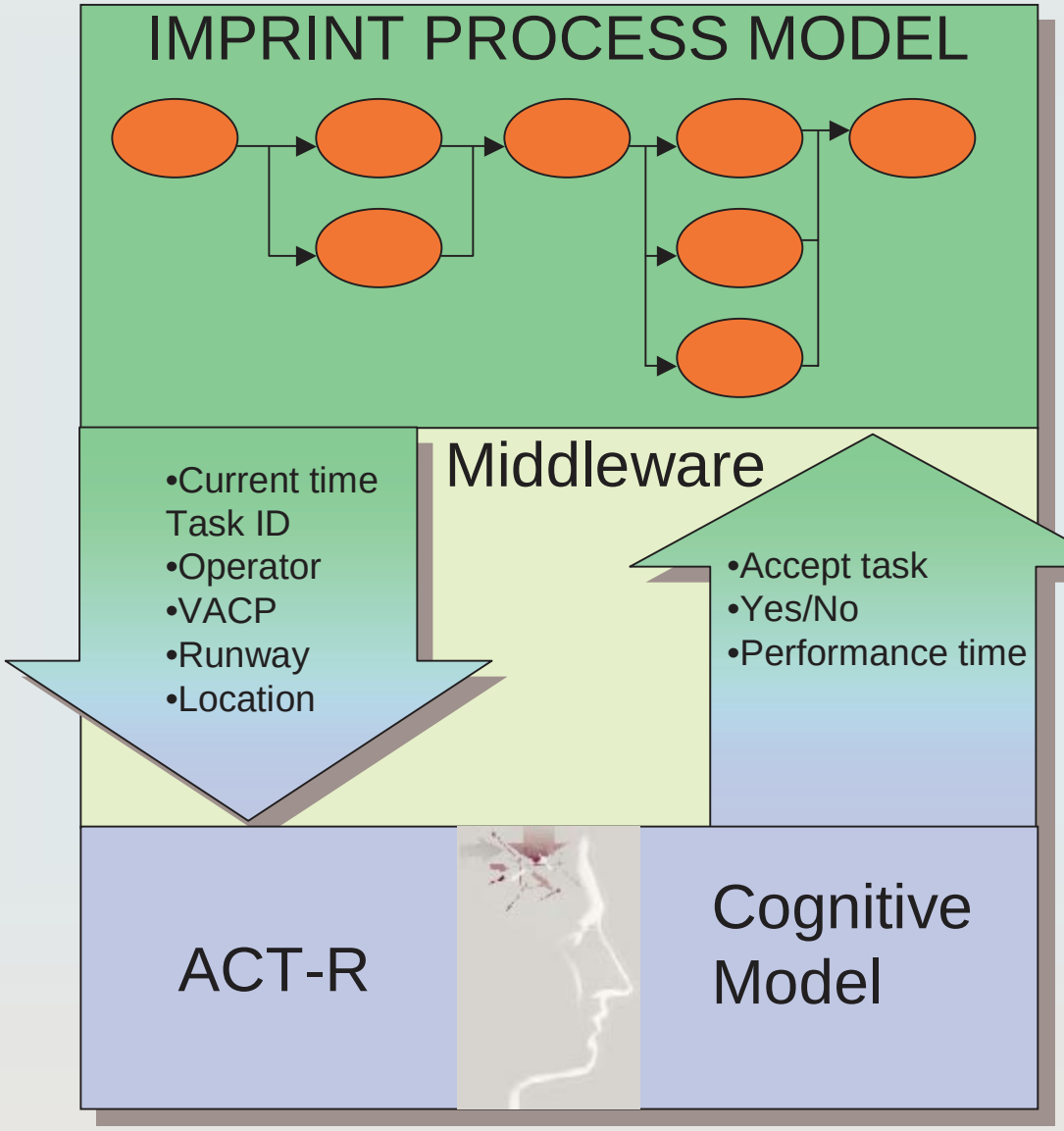
- Omission
  - Forgot a where chunk (activation decay, noise)
  - Error: go straight instead of turn
- Commission 1
  - Remembers wrong runway (interference, similarity, priming, activation noise)
  - Error: turns on wrong runway or misses turn
- Commission 2
  - Remembers wrong turn (interference, noise)
  - Error: makes wrong turn on correct runway

IMPRINT Interoperability Features

- Component Object Model enabled
- External variables
- External application calls

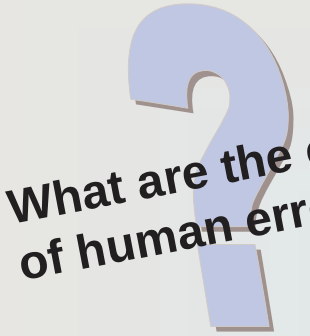


The IMPRINT / ACT-R Approach



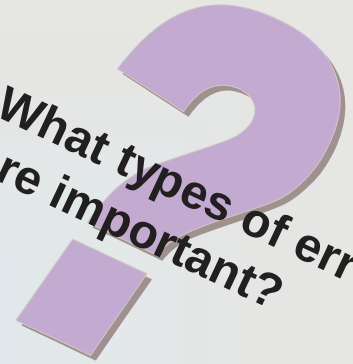
IMPRINT tasks correspond directly to ACT-R goals

Central Questions

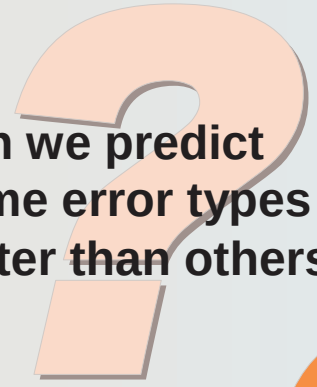


What are the causes of human errors?

What are our most critical assumptions?

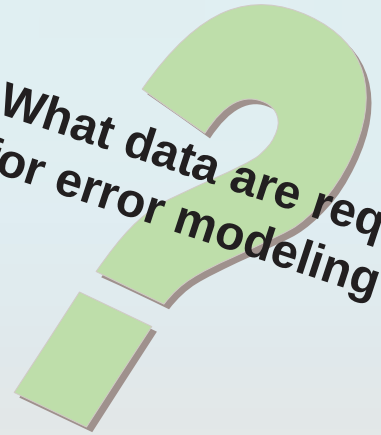


What types of errors are important?



Can we predict some error types better than others?

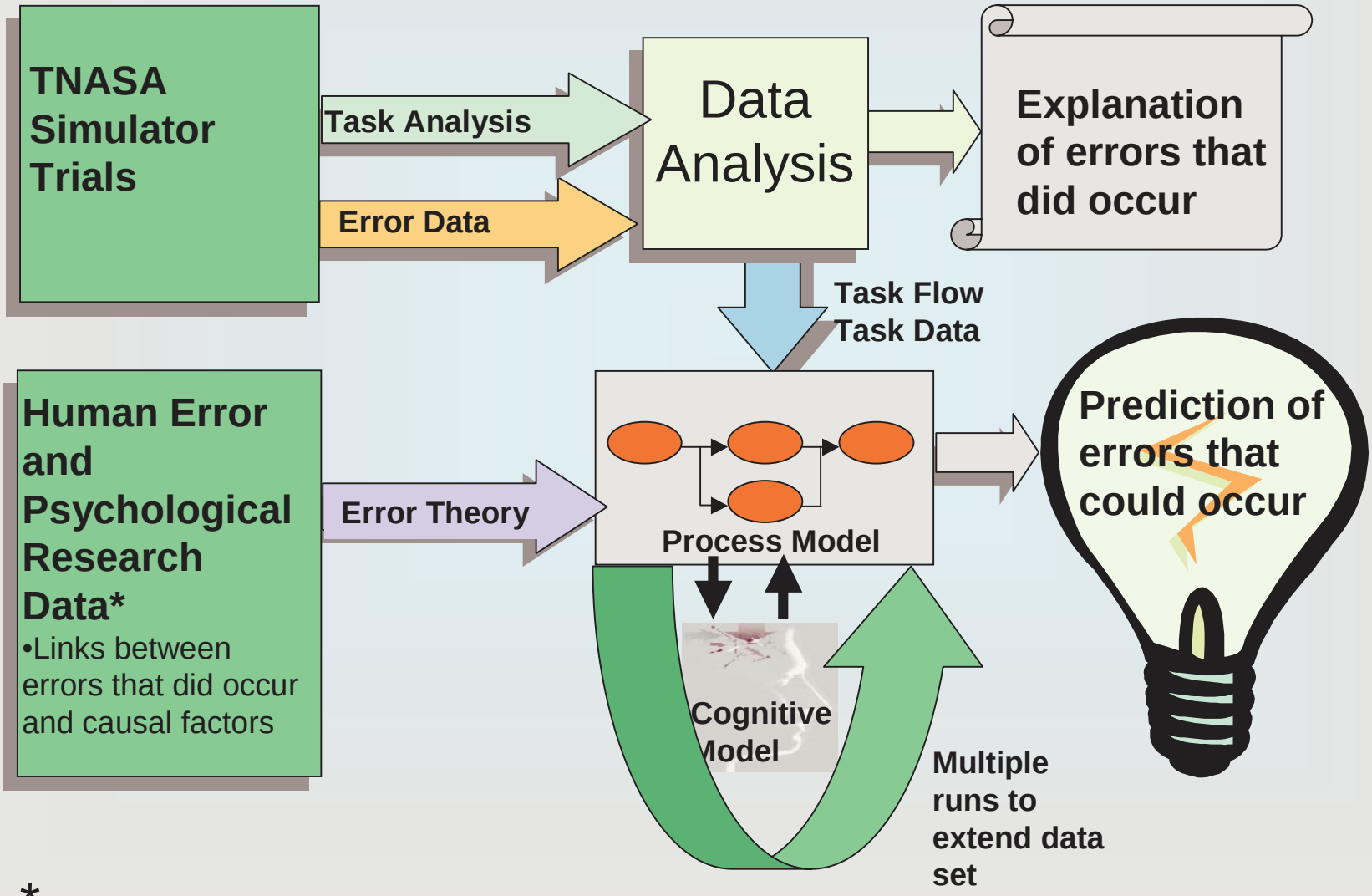
Can we predict vs explain errors?



What data are required for error modeling?

Can we validate conclusions?

Predicting vs. Explaining Errors



* Reason, Rasmussen, Norman

Theoretical Background

- Major theories of human error
  - Norman (Slips, lapses and mistakes)
  - Rassmussen (Skill, rule, knowledge (SKR))
  - Reason (Generic Error Modeling System)
- Good taxonomies (one structured from an overall theory of human cognition) of human error can help to aid in the identification of the underlying causes of error (Reason, 1990)
- However, taxonomies can be ambiguous, vague and overlapping (Busse, 1998)
- A model of human error is a inextricably bound up with "computational primitives" by which [knowledge is stored and retrieved]. (Reason, 1990)
  - ACT-R is an overall framework of human cognition, so it is well suited for all types of human error modeling. Indeed, through architectural mechanisms such as stochasticity and partial matching, errors are an integral part of performance, not a separate model component

Causes of Human Errors in this Environment

Workload
- High - distraction
- Low – boredom
- Transition

Memory decay

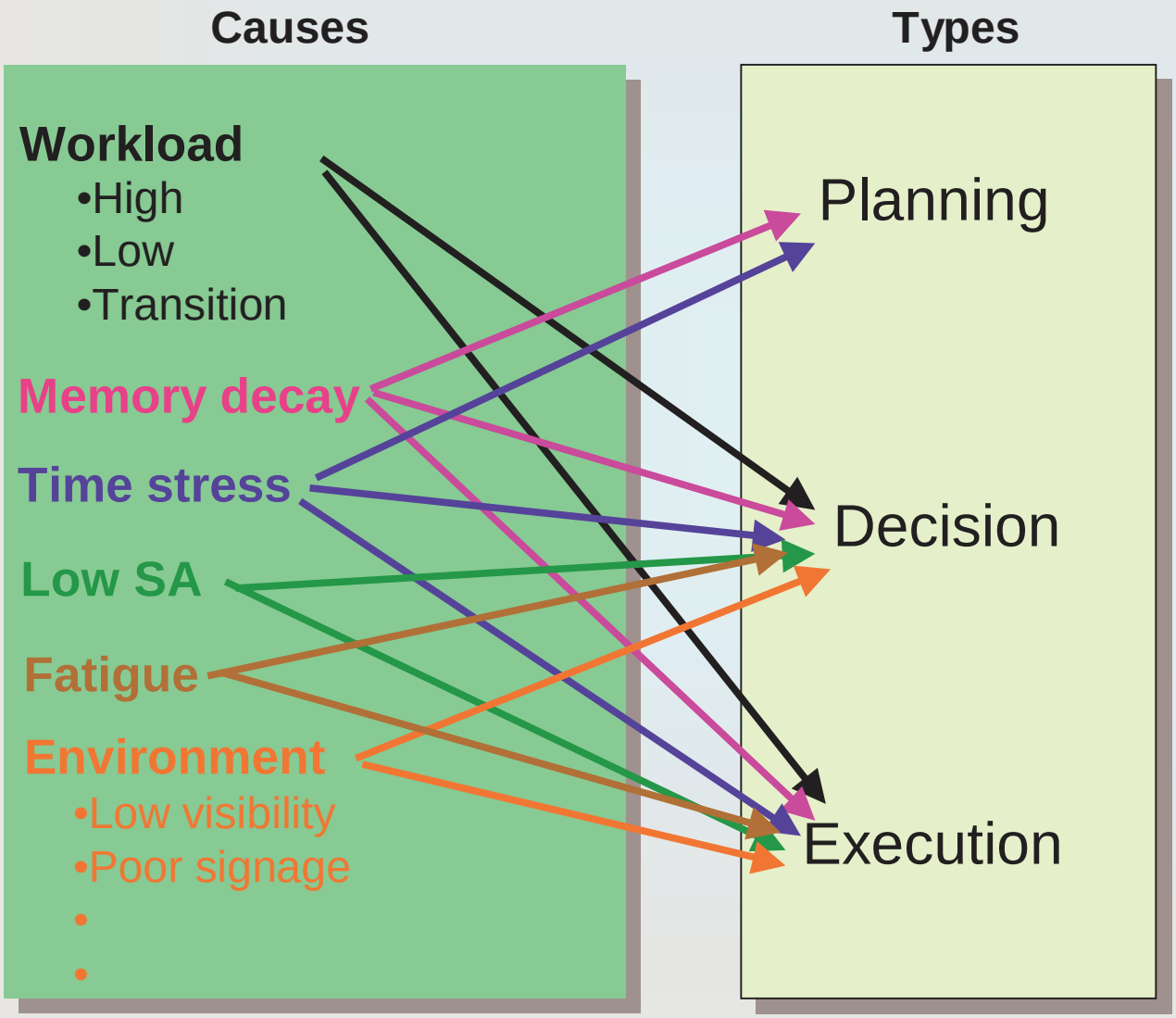
Time stress

Low situation awareness

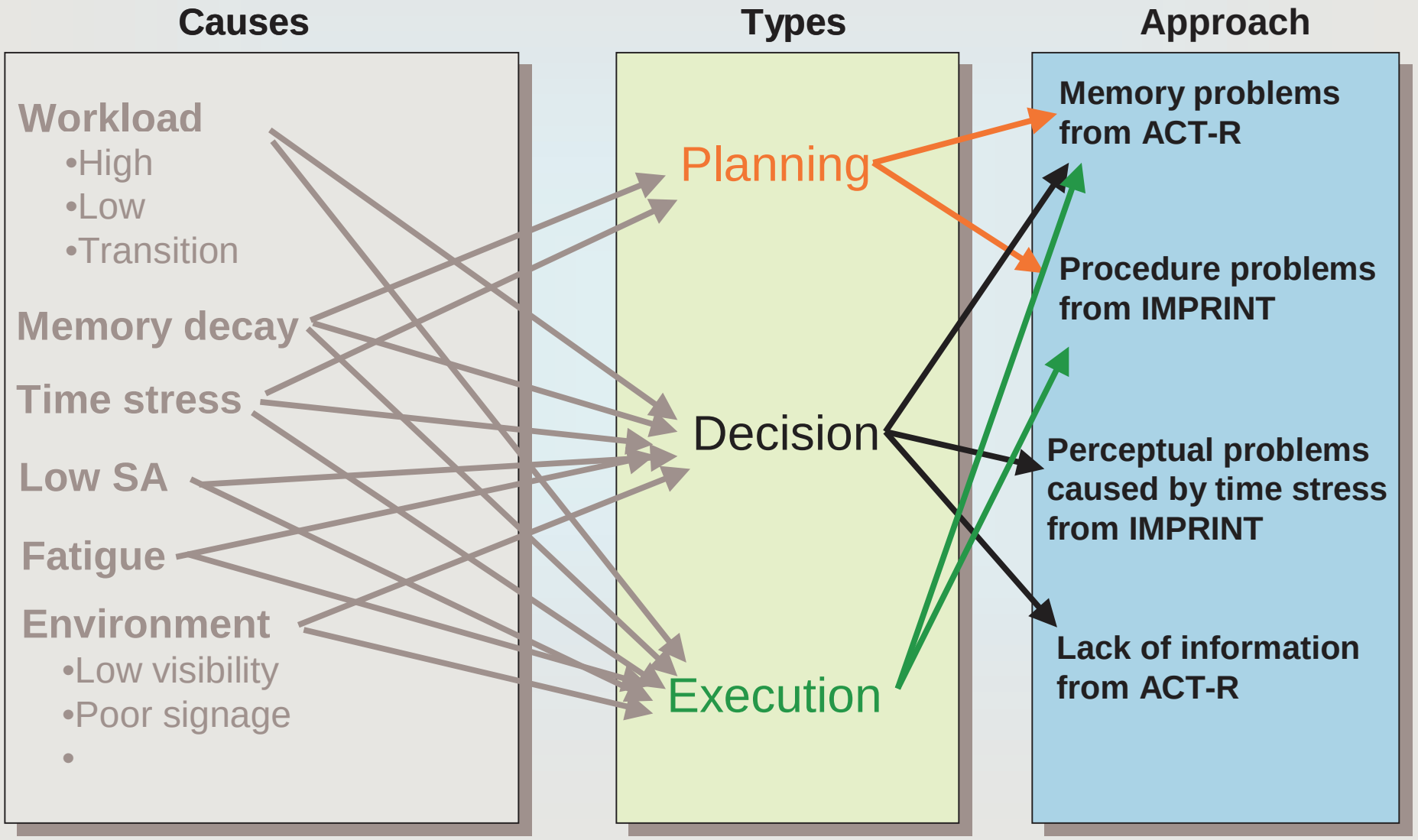
Fatigue

Environmental effects
- Low visibility
- Poor signage
-
-

Types of Errors We Can Predict



Error Modeling Approach



Implementation Details

- **•Memory problems from ACT-R**
  - •Time-based decay of route information
  - •Similarity-based interference between runway and direction memory chunks
- **•Procedure problems from IMPRINT**
  - •Branching logic built-in for alternate procedures
  - •Skipping tasks or doing tasks differently is supported
  - •External events cause new goals (actions) or are ignored due to higher priority goal(s)
- **•Perceptual errors caused by time stress from IMPRINT**
  - • Time available to do tasks or groups of tasks can be computed and used to affect performance (time, accuracy)
  - •When not sufficient time to view sign or turn on runway, info from sign not passed to ACT-R or turn opportunity missed
- **•Lack of information from ACT-R**
  - •Declarative knowledge of airport layout
  - •Procedural knowledge of map reading

Data Requirements

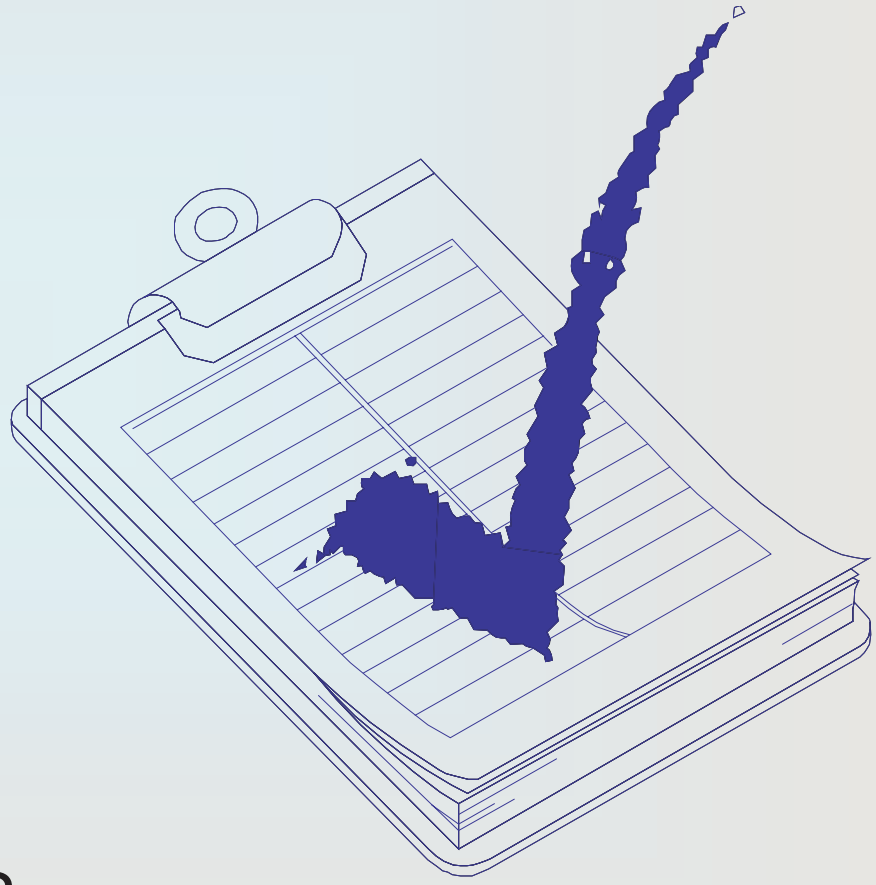
- Task data
  - Performance
  - Flow
  - Operator assignment
  - Priority
- Scenario
  - Runway setup
  - Signage
  - Incoming communication load
- System
  - Speed
- Environment
  - Visibility

Scenario Events for NASA HEM effort

- Using O'Hare maps
  - Calculated estimated time between runway turnoffs
    - distance between runway turns x assumed ground speed
  - Calculated estimated time available to view sign
    - distance to signage x assumed ground speed
- Times checked with video
  - Our calculations resulted in shorter times, possibly due to less conservative ground speed estimates
- Events used by IMPRINT to cause tasks to be triggered

Validation

- Validation of the approach
  - Is it efficient?
  - Does it address the central questions?
- Validation of the model
  - Does it accurately predict human error?



Summary

- Unique approach
  - Combining two separate types of models
  - Play to each model's strength
- Extensible to different airports
  - Scenario-driven task network
  - Network itself is stable
- Extensible to technological aids
  - Relevant model part needs to be updated
- Validation work is needed